Sizing Electric Power Systems
For Model Aircraft

Flightline Hobby Seminar
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Four Ps of Electric Power

- Power
- Pack
- Pitch Speed
- Prop
1) Power

- Power to weight ratio critical to performance
- **For typical sport flying > 100 watts/lbs**
  - Prop/battery may be less than motor capacity
  - Three bladed prop will be less efficient
  - Consider motors rated 100 to 150 watts/lbs
- **For 3D flying ~ 200 watts/lbs**
- **Scale flying possible with ~ 80 watts/lbs**
1) Ultra Micro

- ESC max current = 2.0 amps, ~ 8 watts (est)

- 1S UMX models
  - T28 1.4 oz 8 / (0.087) = 92 watts / lbs
  - P51 1.5 oz 8 / (0.094) = 85 watts / lbs
  - F4U 1.6 oz 8 / (0.100) = 80 watts / lbs
1) Gliders: Parkzone Radian

- ESC max current = 30 amps, ~ 300 watts (est)
  - †25 amps * 12v ~ 300 watts
- 30 oz = 1.9 lbs
- 300 / 1.9 = 160 watts / lbs

†Assumes ESC is not maxed out
1) Gliders: Eflite Mystique

- 4.4 lbs
- Power 25, 600 watts recommended
- \( \frac{600}{4.4} = 136 \text{ watts} / \text{ lbs} \)
1) Motor Kv

- Kv (no load rpms per volt)
- Kv * Volts = no load RPM
  - Higher Kv (in general)
    - Smaller props and/or lower voltage packs
  - Lower Kv (in general)
    - Larger props and/or higher voltage packs

- Voltage * Kv ~ 12,000 RPM similar to glow
- RPM in flight ~ 10,000 RPM (80% of no load)
1) Typical Motor Kv

<table>
<thead>
<tr>
<th></th>
<th>Type</th>
<th>Kv</th>
<th>RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S (240)</td>
<td>Sport</td>
<td>2,500</td>
<td>20,000</td>
</tr>
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<td>Scale</td>
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<td>8,900</td>
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<tr>
<td>4S (3200)</td>
<td>Sport</td>
<td>740</td>
<td>11,840</td>
</tr>
<tr>
<td>4S (3200)</td>
<td>3D</td>
<td>1,000</td>
<td>16,000</td>
</tr>
<tr>
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<td>525</td>
<td>12,600</td>
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## 1) Typical Motor Kv

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Sport planes typically around 12,000 RPM (no load).

Kv * pack voltage ~ 12,000 RPMs in level flight approximately 10,000 RPM.
## 1) Typical Motor Kv

<table>
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<tr>
<th>Model</th>
<th>Type</th>
<th>Kv</th>
<th>No Load RPM</th>
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*Fast prop jets or 3D planes may have a no load RPM higher than 12,000 RPM.*
1) Typical Motor Kv

- 2S (240) Sport - 2,500 Kv - 20,000
- 3S (2400) Sport - 2,200 Kv - 25,200
- 3S (2400) Sport - 960 Kv - 11,500
- 4S (3200) Sport - 740 Kv - 11,840
- 6S (3200) 3D - 525 Kv - 12,600

Many motors provide a choice of no load RPMs.
Fewer cells (lower voltage) = lower RPMs, bigger prop.
More cells (higher voltage) = higher RPMs, smaller prop.

The higher voltage set up will draw less current to generate the same power. Typically, this will make higher voltage systems more efficient.
1) Brushless Motors

- Voltage is speed
- Current is torque
- Often more than 80% efficient
  - When operating at the designed load
  - Voltage and prop determine load
1) Brushless Motors

RPM = Kv * volts

RPM ~ Kv * volts .80*

*Assumes the prop is recommended for that motor and voltage
1) Example

- To electrify a Four Star 40:
  - Weight ~ 5 lbs
  - Power range 500 to 750 watts continuous:
    - Eflite Power 32 (700 watts, 770 kV) 3 to 5 S
    - Rimfire .32 (850 watts, 800 kV) 4 S Recommended
      - Rimfire 25 was only 650 watts max continuous
      - With 4S pack and prop, power likely to be less than 750 watts
1) Example

- Manufacturer recommendations

### RimFire .32

- Includes prop adapter and motor mount.

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<table>
<thead>
<tr>
<th>Description</th>
<th>Stock No.</th>
<th>Diameter</th>
<th>Length</th>
<th>kV</th>
<th>Constant Watts</th>
<th>Burst Watts</th>
<th>Weight</th>
<th>Shaft Diameter (mm)</th>
<th>Voltage Range</th>
<th>Sport</th>
<th>3D</th>
<th>Power System Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RimFire .32</td>
<td>GPMG4700</td>
<td>42 mm (1.7 in)</td>
<td>50 mm (2.0 in)</td>
<td>800</td>
<td>850</td>
<td>1480</td>
<td>198 g (7 oz)</td>
<td>5 mm (0.2 in)</td>
<td>11.1-14.8V / 3-4S LiPo</td>
<td>2950 g (6.5 lbs)</td>
<td>1845 g (4 lbs)</td>
<td>45 Amp</td>
</tr>
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Source: Electrifly.com
1) Power

- Power to weight ratio critical to performance
- **For typical sport flying** $> 100$ watts/lbs
  - Prop/battery may be less than motor capacity
  - Three bladed prop will be less efficient
  - Consider motors rated 100 to 150 watts/lbs
- For gliders $\sim 150$ watts/lbs
- For 3D flying $\sim 200$ watts/lbs
- Scale flying possible with $\sim 80$ watts/lbs
2) Pack

- Voltage (Volts)
- Capacity mAh
  - 1 amp*hour = 1 amp for 1 hour
  - 1,000 mAh = 1 amp*hour

*LiPo battery packs assumed*
2) Pack Voltage

- LiPo cell voltage range 3.75 to 4.20 volts
  - Longer life if voltage kept in this range
  - Voltage measured open circuit (no load)

3.82 V ~½ flight

It is best to charge at room temperature. When cold, voltage drops.
2) Pack Voltage

- For initial estimations, a nominal 4 volts per cell can be used.
  - 1S ~ 4 volts
  - 2S ~ 8 volts
  - 3S ~ 12 volts
  - 4S ~ 16 volts
2) Pack Current

- Watts = V*I
- I = Watts/V
  - For a 750 watts motor:
  - For 3S: 750 / 12 = 62 amps
  - For 4S: 750 / 16 = 47 amps
- Loss = I^2 * R
- *Higher voltage systems more efficient*
2) Pack Capacity

- Initial Estimate:
  - $Ah = \frac{\text{max current}}{15}$ (high performance)
  - $Ah = \frac{\text{max current}}{12}$ (longer flight time)

4S (3200) 750 Watt Example:
- Max current 47 amps
- $Ah = \frac{47}{15} = 3.2 \text{ amp/hrs}$
- mAh = $Ah \times 1000 = 3200 \text{ mAh}$
2) Pack Capacity UMX

• Initial Estimate:
• Ah = max current / 15 (high performance)
• Ah = max current / 12 (longer flight time)

• Example:
  – Max current = 2 amps
  – $2 / 15 = 0.133 = 133\text{ mAh}$
  – $2 / 12 = 0.167 = 167\text{ mAh}$

Stock Battery
150 mAh
2) Pack Capacity Gliders

- **Mystique Example ~ four climbs:**
  - Max current = 44 amps
  - $44 / 15 = 2.9 = 2900$ mAh
  - $44 / 12 = 3.7 = 3700$ mAh

- **Stock Battery**
  - 3200 mAh
  - 30C

- **Single Climb:**
  - $44 / 30 = 1.5 = 1500$ mAh (1300 mAh standard)
  - Max current = 44 amps * 30 seconds = 367 mAh
  - 30C * 1.3 = 39 amps
  - 45C * 1.3 = 58 amps

**Note:** Consider batteries rated over 30C when total powered flight time is ~4 min or less.

- **In theory**, a 1300 mAh 45C battery should climb once
2) My Favorite Packs

- 2 to 2.5 lbs sport planes
  - 3S 2100 packs, ~ 350 watts
  - Economical batteries, many park fliers
    - Parkzone Corsair, T28, SE5a, Multiplex Fun Cub, Flyzone Tidewater, many others
2) My Favorite Packs

- 4 to 5 lbs sport planes
  - 4S 3200 packs, ~ 750 watts
  - Enables a flatter prop than 3S systems
    - Reduced yaw and roll on take off
    - More critical for 3D
  - Efficiency of higher voltage than 3S
    - Carbon Z yak
    - Optional for others specifying 3S 3300 mah pack
      - Eflite Rhapsody, .15 Ultimate Bipe
2) Pitch Speed

- The theoretical speed a plane would fly with no drag
- Actual top speed will typically be ~70% to 90% of pitch speed depending on how much drag the airplane has and the prop. This is very hard to estimate precisely.
3) Pitch Speed

• Cool rule of thumb:

At 10,500 RPM

Pitch Speed = Pitch x 10

13x8 = 80 mph
14x7 = 70 mph
14x6 = 60 mph  (at 10,500 RPM)
3) Pitch Speed

At 10,500 RPM

Pitch Speed = Pitch X 10

Four Star 40 prop 11x7 = 70 mph

Glow engines in the air run ~ 10,000 RPM
(Not RPM on the stand)
The recommended glow prop gives a good idea what pitch speed is good for the model
3) Pitch Speed

- Adjust estimate based on expected RPM

**At 8,400 RPM**

(80% of 10,500)

13x8 = 80 x .80 = 64 mph
14x7 = 70 x .80 = 56 mph
14x6 = 60 x .80 = 48 mph

Increase Kv or voltage to raise RPM up to 10,500 if a prop similar to a glow prop is desired.
3) Estimating Pitch Speed

\[ \text{RPM} = \text{Kv} \times \text{volts} \]

*RPM \sim \text{Kv} \times \text{volts} \times 0.80*

*Assumes the prop is recommended for that motor and voltage*
3) Example

- To electrify a Four Star 40:
  - Eflite Power 32 (700 watts, 770 kV) 3 to 5 S

Power 32 / 4S pack no load speed = 770*16 = 12,320 RPM
12,320 * .8 = 9850 RPM

9850/10500 * 10 * 7 = 66 mph

Using a 4S pack lets you use a 12x7 prop. The same prop as recommended with a Saito 56 glow.
3) Glider Examples

• Radian Glider
  - 960 Kv * 12v * 0.80 = 9200 RPM (flying)
  - Pitch = 7.5
  - \((9200 / 10,500) \times 7.5 \times 10 = \textbf{66 mph}\)

• Mystique Glider
  - 870 Kv * 12v * 0.80 = 8300 RPM (flying)
  - Pitch = 8.0
  - \((8300 / 10,500) \times 8.0 \times 10 = \textbf{63 mph}\)
4) Prop Diameter

- Larger diameters grab more air, typically generate more thrust
- Larger diameters take more power
- Clearance can limit prop size
- Three blade props less efficient than a larger two blade prop, but sometimes used when clearance is an issue.

Electric props are thinner, more efficient than glow props
P/D = 1/1: “square prop” 5x5, 6x6, 7x7 – Stalled at take off
P/D = 1/1.5: 9x6, 12x8, 15x10 – Typical for Sport
P/D = 1/2: 12x6, 14x7, 16x8 – Better for 3D, consistent speeds
Confirm Current Draw

- Ecalc.ch or other simulator
  - Valuable for optimizing prop (especially diameter)
  - Estimating flight time
- Refer to manufacturers recommendations
  - For motor AND pack voltage
- **Power meter recommended for new systems**
Common Connectors

- **JST**
  - For small indoor fliers, < 5 amps

- **EC3 (blue connectors)**
  - 60 amp max current
  - Can be separated with snap ring pliers

- **Deans Ultra Plug (red T connectors)**
  - ~60 amp max current

- **EC5 (max current 120 amps)**
Summary

- Power (> 100 watts per lbs)
- Pack (~ 4 volts per cell)
  - My favorite packs 3S 2100, 4S 3300
- Pitch Speed (mph)
  - At 10,500 RPM = 10 * Pitch (inches)
- Prop D/P ratios
  - > 1.5 improve low speed handling
  - 2.0 or greater for 3D
- Confirm setups with watt meter
  - Props vary